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6.—The Woolgorong Stony Meteorite

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Numerous fragments of a stony meteorite were recovered from Woolgorong Station, north-north-east of Mullewa, Western Australia and approximately 300 miles north of Perth in July, 1961, and later in the same year. This find almost certainly represents a possible fall noted in this locality in December, 1960. A double report was heard at this time, but the authors consider that this does not necessarily imply a multiple fall since phenomena of this kind are generally attributed to compression wave effects high in the atmosphere. The meteorite is a veined and brecciated, grey hypersthene-olivine chondrite, Prior's class III, and shows evidence of pronounced recrystallisation. Recovery of fragments from shallow burial in the soil and from the surface, has allowed a confident reconstruction to be made. There is evidence that it had an aerodynamically stable form under conditions of atmospheric entry, since surface patterns and the distribution of thickened and thinned fusion-crust reveal a distinct orientation. Such orientation supports the idea that this was a single fall, complicated only by fragmentation at or near the point of impact.

Microscopic study has revealed considerable structural variation, some areas revealing well-formed, though recrystallised, chondrules. Others show almost complete recrystallisation to a granular aggregate of polysomatic and larger fractured grains. In these areas of recrystallisation the chondrular structure is only vaguely defined.

Chemical tests, etch-tests, X-ray diffraction studies and two full chemical analyses have been carried out, and the results are given here. The minerals determined include kamacite, iron sulphide (troilite?) olivine (chrysolite-hyalosiderite), orthopyroxene, oligoclase, and possibly a calcium silicate (rankinite?).

Introduction

In August, 1961, the report of a possible meteorite discovery reached the Geological Survey of Western Australia (Lord, unpublished data). The report came from Mr. F. R. Wickman, Manager of Woolgorong Station (Fig. 1), the site of the discovery (latitude 27° 43′ S, longitude 115° 50′ E).

This discovery followed seven months after the experience of unusual phenomena including sounds normally associated with explosions, heard by people at or near the Station. Even at that time the possibility of a meteorite fall was discussed, though the possibility that an aircraft in distress was involved was also suggested, and indeed an air search is reported to have been initiated. The meteorite was recovered as a direct result of attempts to locate the object which had caused this disturbance.

The detailed investigation of this fall was passed over to the Director of the West Australian Museum, Dr. W. D. L. Ride, and he visited the site of the find with Mr. D. Merrilees later that year, recording details of personal impressions of the 1960 phenomena and examining the traces of the fall. They collected further fragments of the stone, in addition to those originally collected by Mr. A. J. Noldart of the Geological Survey of Western Australia (Lord, unpublished data).

At the request of Dr. Ride, the investigation has been supervised in its later stages by honorary associates of the Museum, members of the Meteorite Advisory Committee which acts in an advisory capacity to the Trustees of the Museum; Dr. McCall, who has supervised petrographic and chemical investigations, and compiled the information here given concerning details of the fall and external features of the meteorite; and Dr. Jeffery who has carried out X-ray diffraction studies. The actual chemical analysis was carried out at the British Museum (Natural History), London: an additional X-ray diffraction determination was also carried out at the British Museum (Natural History).

This meteorite was initially supposed to be achondritic—if this was correct it would have been an exceedingly rare occurrence; however, access to the whole collection of recovered fragments showed that initial microscopic studies had been carried out on a very strongly recrystallised area within the stone, an area showing little trace of rounded chondrules, and that the bulk of the fragments show distinct, rounded chondrular insets. While the find is not as rare as was at first suspected, the amount of material recovered, the diverse internal texture and structure, and the excellent preservation of external features characteristic of oriented meteorites, make this one of the most interesting meteorite finds in this State.

History of Fall and Reconstruction of Meteorite

Discovery of the Meteorite

In July 1961, Mr. W. Hamlet and Mr. C. Monger both employed at Woolgorong Station, unearthed what they called a "sky stone" at a point situated a few hundred yards north-west of the Station homestead. A shallow crater some twelve inches deep had been formed in the

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topsoil, and the mass had apparently disintegrated into angular fragments on impact. The manner in which the crater was gouged into the soil suggested (to those who have visited the site) impact at a reasonably shallow angle of incidence, and no abnormal velocity, on a flight bearing of 320°—that is, close to north-west. The preservation of a trail of small meteorite fragments and dust along the same trend line supported this conclusion. Some larger fragments were collected up to three feet from the small crater, perhaps due to rebound on impact. The geologist of the Geological Survey of Western Australia who first visited the site reported that the site of the fall was a broad, flat plain of red soil, which overlies a thick, indurated crust of the type locally known as the "Murchison Cement."

The Reported Fall

It must be borne in mind that all the reports bearing on the phenomena observed in December, 1960, were made to Dr. Ride and Mr. Merrilees a year later. However, they correspond so closely with other descriptions of meteorite falls, contained in the literature, that there seems no reasonable doubt that the meteorite fell at this time.

As is not uncommon, auditory effects predominated—the only visual observation recorded being a slight haze or dust cloud noted by Mr. F. R. Wickman, who was at the homestead on the afternoon shortly before Christmas, 1960 (Dec. 20th?) and at about 1400 hours heard a swishing noise followed by a dull bang "like a couple of plugs of gelignite going off forty feet underground." The suggestion of two distinct reports, one at Woolgorong and one to the north-north-west, towards Yallalong (Fig. 1) is present in several recorded descriptions of this event. At Yallalong a noise was heard which suggested that an aircraft was in distress, and it is said that a light aircraft actually took off to search for it. Though this record of a double report could mean a double fall—meteorites do, in fact, usually fall in multiple associations rather than as single bodies—such sound effects are more commonly attributed to compression waves high in the atmosphere, as the still speeding meteorite enters the atmosphere and commences to decelerate (an effect akin to the supersonic bangs of jet aircraft). The evidence of orientation (p. 38) suggests that this was in fact, a single fall up to the point of fragmentation at or near contact with the ground. If a second stone does exist, the nature of the terrain and the rapid deterioration of stony meteorites are factors likely to preclude further recovery.

The reports were heard up to thirty miles from the homestead at Woolgorong, and this in itself supports the idea that the sound effects were due to shock-waves—it is unlikely that the report produced on impact with the earth of a mass of about one hundred pounds weight could ever be heard so far from the point of impact. Stones of this size reach the surface of the earth at a velocity in no way comparable with their velocity through space because of the effect of atmospheric braking, and the shallow and partial burial of this meteorite testifies to impact at a velocity probably not far off, or at, the speed of free fall: the close association at the site of the find of the fragments which were later pieced together with perfect interlocking junctions testifies to very late fragmentation, probably on impact, though the cracks had clearly started to form before this time.

Mr. Hamlet recalls a loud report and a noise like a thunderstorm, but saw no flash; Mrs. Wickman likened the noise, again, to an aircraft in difficulty, and believes that a short (but appreciable) pause separated the two reports.

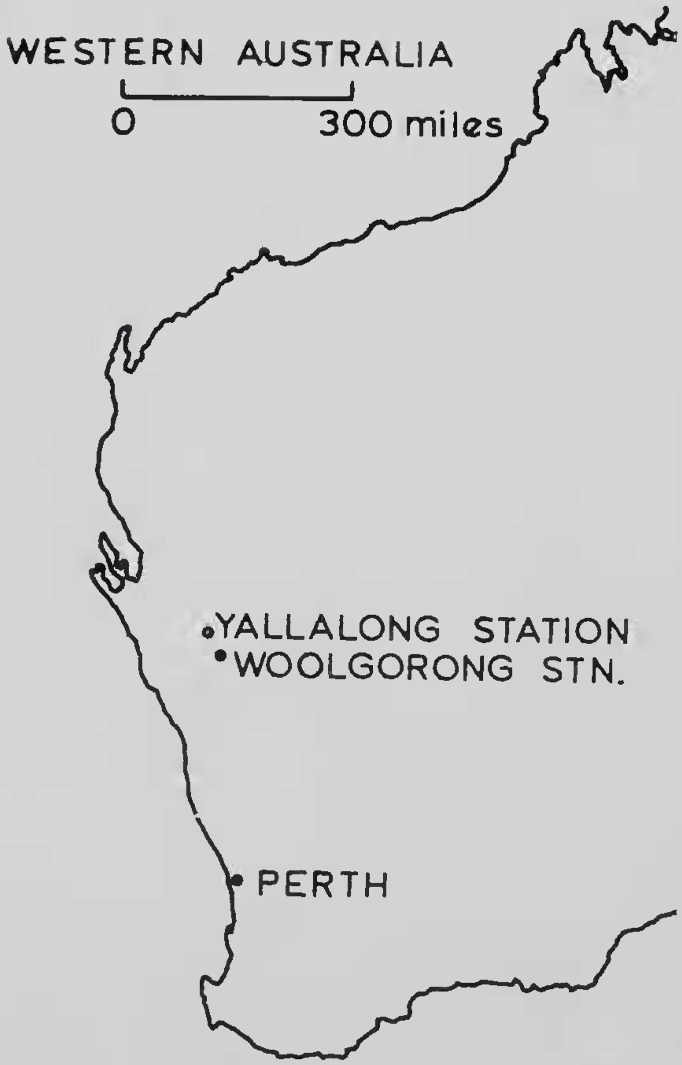

Fig. 1.—Sketch map showing the position of the Woolgorong fall and meteorite recovery.

The Meteorite Fragments

A total weight of about eighty pounds of fragments has been recovered. Of these the bulk, comprising five large and numerous smaller fragments are held at the West Australian Museum (W.A.M. No. 12113 a, b and c).* Another large, fusion-crust coated fragment, weighing 7½ lb., was retained at Woolgorong Station.

Two small fusion-crust coated fragments are held in the collections of the Geological Survey of Western Australia and the Government Chemical Laboratories. Another such fragment has been supplied to the Keeper of the Mineralogical Collections at the British Museum (Natural History).

* Some of the material collected was temporarily stored in contact with galena samples. Any geochemical work on trace element content should therefore be restricted to specimens marked 12113b which are not so contaminated.

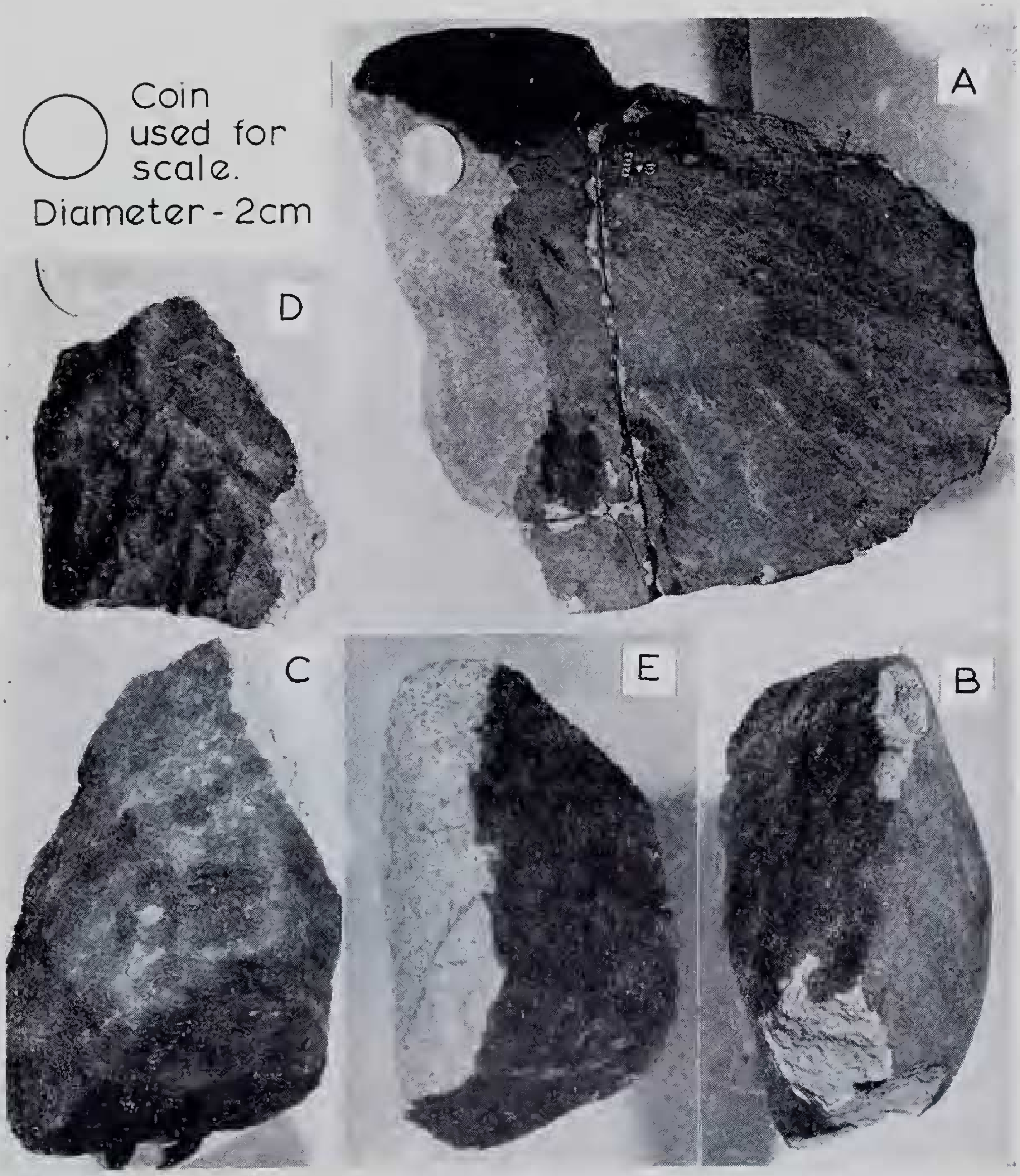

Plate 1. A. Some larger fragments fitted together to reassemble the entire termination of the original mass (eight fragments can be fitted together exactly, but an assemblage of only four is shown here). The thin, brown fusion-crust which covers the surface contrasts with a grey, freshly-broken surface revealed on the left hand side of the photograph. This surface is believed to be the anterior surface. Radiating striae and regmaglypts show clearly on the surface of fusion-crust (coin indicates scale).

B. End-on view of the same reconstructed termination showing contrasting fusion-crust surfaces, the posterior surface in atmospheric flight being rough, blackened and thickened (scale as above).

C. Facetted fragment from the opposing termination of the original mass (scale as above).

D. Fragment showing elongated regmaglypts.

E. Fragment showing the thickened fusion-crust of the posterior surface, contrasting with that shown in Plate 1 A above (X ½).

The fragments show mostly freshly-fractured surfaces, appearing grey with patches and streaks of iron oxide staining, and are of moderately coarse grain. Specks of metal punctuate these broken surfaces, appearing glistening and of grey to brown colour on faces freshly cut with the diamond saw, but rapidly tarnishing to the brown colour seen on all the faces opened up at the actual time of fragmenation. Thin, thread-like veinlets traverse the stone; most are infilled with glassy material, projections of the fusion-crust inwards at the time of incipient fragmentation (Plate 1E). These are apparently what Krinov (1960, p. 190) calls "surfaces of the second kind," which develop only during the final stage of progress of the meteorite through the atmosphere. There are, however, some veinlets infilled with sulphide (p. 38) and these veinings must be due to some process which occurred long before the brief transit of the stone through the terrestrial atmosphere—a process which presumbly occurred within the parent planetary body.

Rounded chondrules show clearly on some broken surfaces: some are up to half a centimetre in diameter, and most of them are composed of ferromagnesian silicates showing bluish-grey within the lighter grey granular base, and not apparently aggregated with any metal or felspar. Metallic chondrules of similar rounded shape are not numerous, but can be recognised; some form solid metallic pellets up to half a centimetre in diameter but most are of considerably smaller size. In the granular base, which forms considerable chondrule-free areas and encloses the chondrules where these are manifest, creamy-white specks of felspar can be recognised.

Some fracture surfaces show a brecciated appearance, due to the presence of insets of irregular form, appearing as angular fragments (Plate 2B)—these are mostly broken or partly recrystallised chondrules, but some seem to be simply fragments of varying texture—it is however, essentially a monomictous breccia in that all the fragments stem from a single type of stony meteorite.

The fusion-crust is evident on many fragments; it shows a pronounced variation in thickness and character, the thickness ranging from less than 0.5 mm. to more than 0.75 mm., and the areas of thickening (Plate 1E) being characterised by a noticeably roughened surface, black in colour and traversed by a fine network pattern of polygonal shrinkage cracks, the diameter of the polygons being in the order of half a centimetre. In contrast, the fusion-crust shows in the areas of thinning (Plate 1), a smoother surface and a brownish colouration; striations are here more in evidence, but polygonal shrinkage cracks less so. Perfect thumb-print regmaglypts are sparsely indented in the fusion-crust (Plate 2C); the regmaglypts at the border area of the thinned crust, near the sharp coigns in the facetted meteorite (Fig. 2), are however, almond-shaped, and elongated parallel to the finer striations on the glass surface (Plate 1A, D). According to the accepted theory, the circular thumb-prints appear where there is little ablation while the elongated regmaglypts appear where ablation results in strongly linear flow effects. Striae are present on both thickened and thinned areas of fusion-crust, but are far less evident on the rough, black, thickened areas of fusion-crust (Plate 1C) as are shallow regmaglypts.

A

B

C

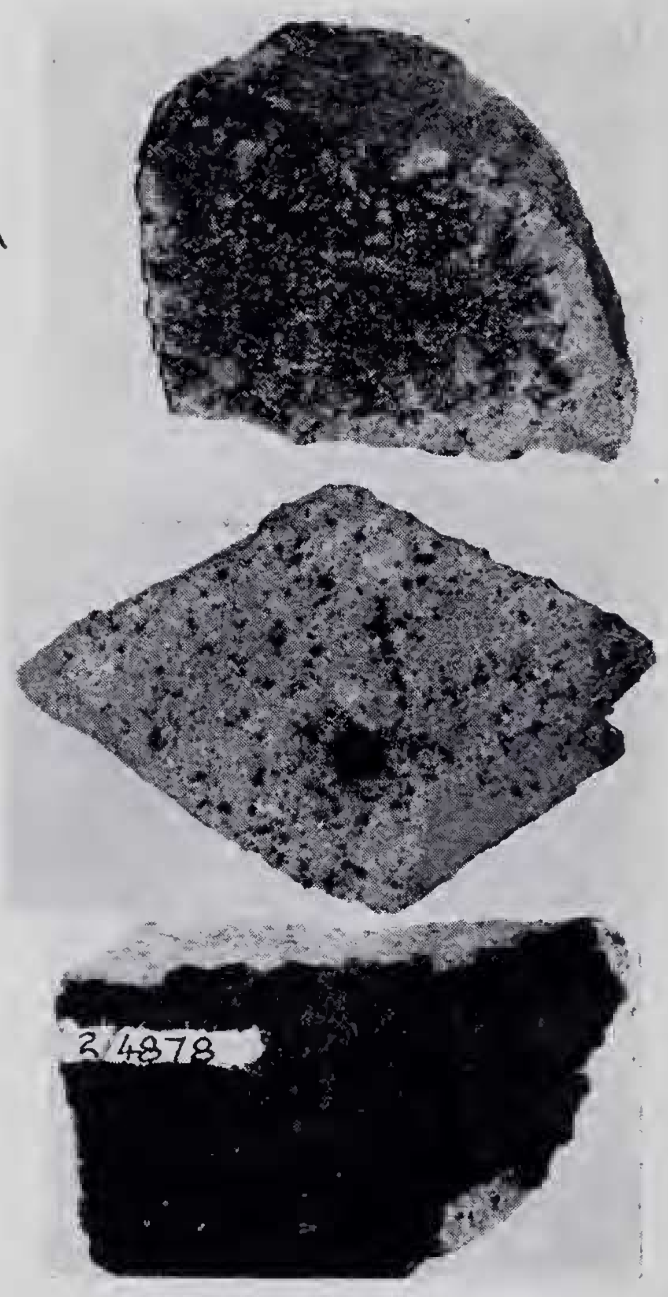

Plate 2. A. Fragment showing a glass-veneered surface due to the fact that the meteorite has fractured along a plane of fracture of the "second kind" (p. 36) (X $\frac{1}{2}$).

B. Cut face of a fragment showing circular and angular chondrular insets of ferromagnesian minerals, giving to the meteorite a brecciated character. The arrangement of the nickel-iron and sulphide along stringers is evident, and there is one large, wholly-metallic chondrular inset (scale, width of the specimen is $2\frac{1}{2}$ inches).

C. Thumb-print regmaglypts (scale X 1.25).

Reconstruction and Orientation

It has not been possible to fit together all the available fragments so as to reconstruct the entire mass, enclosed by fusion-crust, as it was before fragmentation. However, it is probable that at least two-thirds of the mass is represented by fragments held in known collections. The difficulty arises due to the small size of many of the fragments and the fact that a portion from the middle of the mass seems to be not represented by any large fragments. A single termination comprising about one-third of the original mass was successfully reconstructed, the various pieces, numbering eight in all, being joined on tightly-interlocking faces. The reconstruction of four of the largest fragments into this termination is shown in Plate 1A. This reconstruction of one termination of the mass allowed a confident estimation of the length and cross-section shape of the stone, by means of extrapolating the very regular curvature of the faces of this part of the mass. The total length of the mass was probably not more than three feet, the maximum width just over twelve inches, and the maximum depth six to seven inches. The probable shape of the original mass is shown in Fig. 2, together with the fusion-crust patterns.

A fortunate chance in the correspondence of a set of striations and the nature of the crust on the surface of one large fragment with those on the thickened surface of the reconstructed termination, allowed this fragment to be identified and orientated as the opposing termination of the boat-shaped mass. This fragment, shown in Plate 1 C, is drawn in its probable position in Fig. 2. It seems that one termination was spatulate while the other was facetted, and the lateral margins of the flattened boat-shaped mass were also different, one being continuously curved while the other had a steeply-facetted form and was bounded by abrupt coigns.

The pattern of striations, regmaglypts and fusion-crust thickening suggests that this mass had an aerodynamically-stable character while travelling through the atmosphere—that is, it

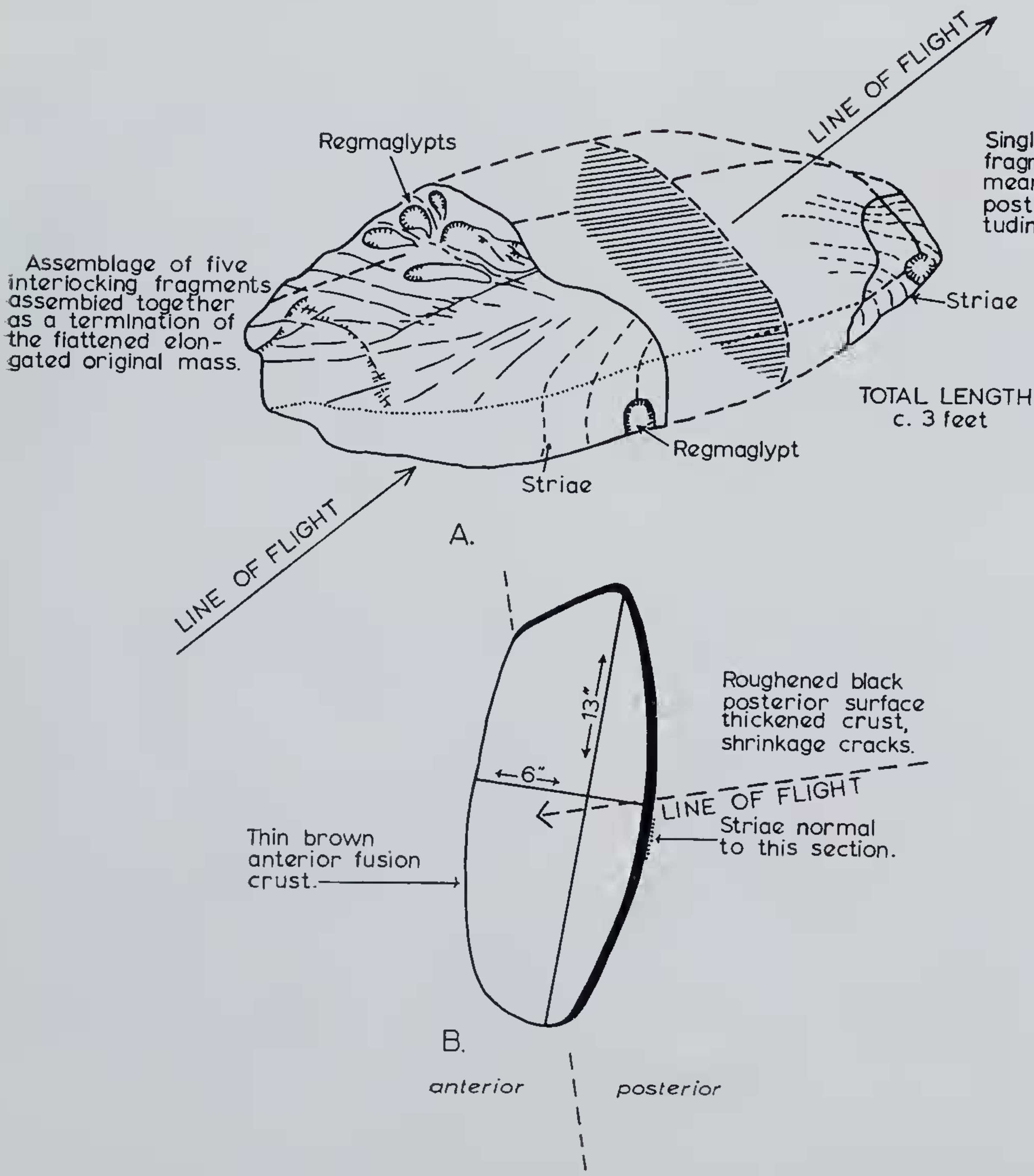

Fig. 2.—Diagrammatic reconstruction of the probable form of the original mass before fragmentation, showing surface patterns and their probable relationship to the attitude adopted by the mass while in atmospheric flight. The cross-hatched plane represents a cross-section of the meteorite.

did not rotate to any extent. This means that it is an orientated meteorite; such a character is somewhat unusual, and is supposed to be evinced by meteorites which have entered the atmosphere as a single mass, and not suffered fragmentation until impact or the very last stage of their transit through the atmosphere. The probable flight attitude is shown in Fig. 2, and the extreme anterior point was probably situated near to the coin, shown to give the scale in Plate 1 A. In spite of the evidence of orientation, the mass does not seem to have been symmetrical.

Petrography

The Metallic Fraction—Megascopic Details

The metallic fraction occurs as grey to brownish specks, stringers and pellets within the stone, and is mostly fringed by hazy, brown iron oxide discolouration of the surrounding silicate minerals. It forms between 10 and 15 per cent. by volume. One large pellet, half a centimeter in diameter was removed bodily, etched with 8 per cent. HNO_3, and tested for nickel and sulphide. Etching revealed a coarse irregular pattern (Fig. 3), clearly not an organised octahedral Widmanstatter pattern. The possibility that this pattern could stem from aggregation of the sulphide within the metallic areas is suggested. That considerable sulphide is present was shown by dissolving some of the metal in concentrated HCl, H_2S fumes being evolved (troilite dissolves in this way); and the reaction with dimethylglyoxime gave a strong pink colouration indicative of nickel.

X-ray diffration studies (p. 42) provided confirmation of the tentative recognition of the principal metal component as kamacite, and the absence of taenite revealed by these studies confirmed that the etch-pattern could not be an octahedral Widmanstatter etch-pattern.

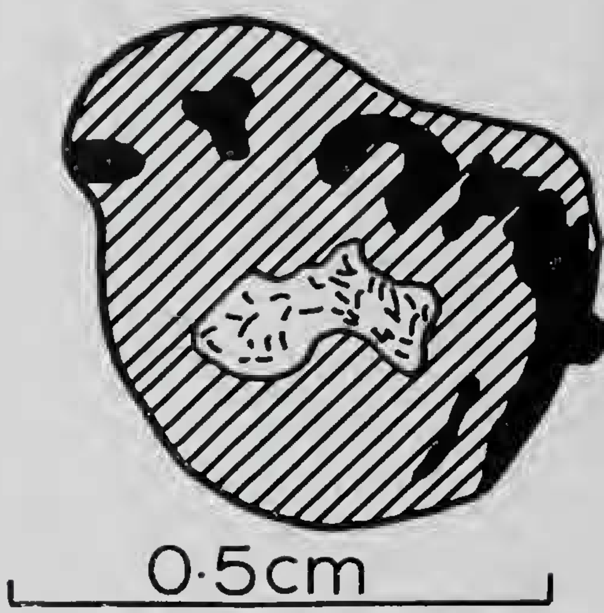

Fig. 3.—Irregular etch pattern developed after etching the cut and polished surface of a large metallic pellet (Plate 2 B) with 8% HNO_3. The cross-hatched area is kamacite, the black enclaves are etch-pits, probably reflecting sulphide inclusions within the nickel-iron. The central area is a deep cavity produced on etching—its origin is uncertain.

The Silicate Fraction—Megascopic Details.

The silicate minerals of meteorites tend to present unfamiliar surface appearances to the petrologist familiar with terrestrial olivine, pyroxenes and felspars. In this meteorite the felspars have the usual creamy-white colour, but the light grey colour of the olivine, and the bluish colour of the ferromagnesian minerals of the chondrules are atypical of terrestrial olivine and orthopyroxenes. The finely-shattered or finely-granular nature of the crystals which is apparent on microscopic examination, probably accounts for this unusual appearance in the hand-specimen. The metal-free and felspar-free character of some chondrules is very noticeable, as is the fact that micro-faulting within the stone has displaced portions of some chondrules relative to the remainder. This, together with the angular and fragmental nature of some chondrules accounts for the brecciated appearance seen in certain areas of the meteorite (Plate 2 B). The light grey colour of the bulk of the silicate fraction, together with the more bluish-grey colour of the chondrules leave no doubt that this should be classified as a grey chondrite (in the older terminology of Brezina), and the structure noted above requires the addition of the term brecciated.

The Metallic and Silicate Fractions—
Microscopic Examination

Under the microscope, the meteorite reveals a predominant content of transparent silicate minerals and subordinate opaque nickel-iron. It is almost free from glass, except for fusion-crust and extensions of it into cracks. The metal percentage is below the upper limit of metal content of aerolites and thus no other appellation can reasonably be given. The silicate minerals are:—

Olivine (var. chrysolite—hyalosiderite)
Orthopyroxene (enstatite-hypersthene)
Plagioclase felspar (var. oligoclase)

Plate 3. A. Photomicrograph. Finely granular chondrule composed largely of orthopyroxene (dark-grey). Felspar (white) and metal (black) fringe the chondrule and stringers of this material tend to terminate at its margins. Vague fan structure is recognisable (X 63, Plane polarised light).

B. Photomicrograph. Another such chondrule, but mainly composed of olivine. It shows similar fringing crystallisation of nickel-iron and sulphide (black) and felspar (white), but here the minerals seem to have "eaten" into the chondrule at its margins, probably in the course of the partially completed process of recrystallisation. Troilite (black) occurs in a veinlet on the right hand side of the photograph, a veinlet of the type that occasionally transects the chondrules (X 63, Plane polarised light).

C. Photomicrograph. A grated chondrule apparently entirely composed of olivine lamellae without associated glass; clearly strongly recrystallised (X 125, Plane polarised light).

D. Photomicrograph. An exocentric fan chondrule, apparently entirely composed of olivine (X 63, Plane polarised light).

E. Photomicrograph. A microporphyritic chondrule consisting of sulphide (black), felspar (white) and dark, dusty aggregates of cryptocrystalline material or glass; this chondrule appears as if partial assimilation has occurred during the recrystallisation process (X 100. Plane polarised light).

F. Photomicrograph. A fan chondrule of cryptocrystalline material or glass (cloudy black), sulphide (black) and felspar (white). Olivine shows as grey granules (X 100, Plane polarised light).

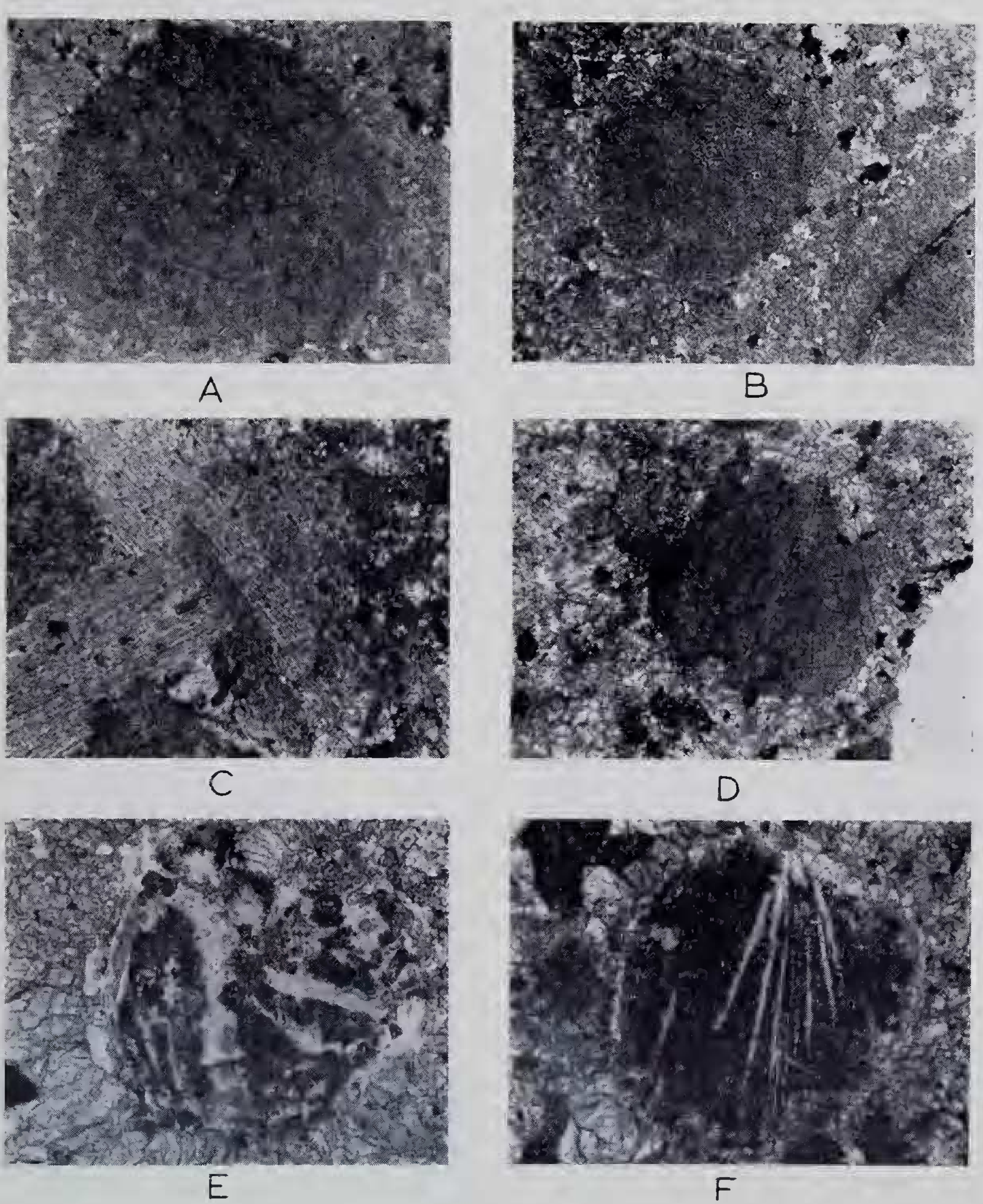

PLATE 3

No other silicate minerals could be optically determined.

Olivine.—Entirely fresh, it shows some evidence of subhedral form in "gabled" terminations of some larger grains, but is mostly anhedral. It may be of somewhat fibrous appearance in the chondrules. Irregular granules tend to show a polysomatic character, being granulated into innumerable minute granules bounded by planes of cleavage and parting within the larger crystal (Plate 4 A, B). The granulation has locally proceeded so far that the granulated aggregates of minute grains bear no trace of the larger grains from which they have been derived. As the dominant silicate mineral, olivine occurs in both chondrules (Plate 3 C, D) and areas of almost complete recrystallisation devoid of apparent chondrules (Plate 4 A); it is evident in the lamellae within grated chondrules (Plate 3 C).

The diagnostic optical characteristics are an interference figure indicating a biaxial mineral with a very large optic angle (c.80°) and a negative sign, and refractive index values ranging from 1.68 to 1.72. These properties fit in with a slightly ferroan variety, compositionally slightly towards the hyalosiderite range from chrysolite ($Mg_{80}Fe_{20}$). This agrees with the chemical determination as probably c.$Mg_{75}Fe_{25}$ (p. 41). This is the typical olivine of Prior's Class III, hypersthene-olivine-chondrite.

Orthopyroxene.—This can be recognised in thin sections on account of better cleavage and lower birefringence than the olivine. It is, however, often difficult to differentiate in fine grains. Present in both chondrules and areas of almost complete recrystallisation, it is of a non-pleochroic variety. The optical sign seems to be negative (though few good interference figures were obtained) and the most probable identity is hypersthene lacking pleochroism. Deer, Howie and Zussman (1963, p. 30) state that in orthopyroxenes the pleochroism is not a factor of increasing iron content but is independent of the MgO/FeO ratio, and thus non-pleochroic, ferroan orthopyroxenes are not unknown. It must, however, be noted that while enstatite is ruled out as a modal component on account of the chemical evidence (p. 41), modal bronzite is possible since Prior's classification (1922) is chemically based and involves assessment of the MgO/FeO molecular ratio in all the

A

B

Plate 4. A. Photomicrograph. A strongly recrystallised area of the meteorite. The finely cracked, polysomatic nature of the olivine grains (grey) is apparent, as is the manner in which the felspars (white) are aggregated interstitially and along stringers with nickel iron and troilite (black) (X 163, Plane polarised light).

B. Photomicrograph. A similar recrystallised area under higher magnification. Kamacite shows black, olivine grey, and oligoclase felspar white. The texture of this area of the meteorite appears not dissimilar from that of many terrestrial igneous rocks (X 320, Plane polarised light).

silicate fraction, while in fact olivine tends to take up rather more iron in proportion to magnesium than orthopyroxene (Prior and Hey, 1953, p. x).

Plagioclase.—Present as colourless interstitial granules, translucent and showing distinct cleavage but only seldom showing lamellar twinning, the felspars are quite fresh. Refractive index determinations and measurements of the extinction angles on a few recognisable lamellar-twinned grains indicated that it has the composition of oligoclase, somewhere between $An_{20}Ab_{80}$ and $An_{28}Ab_{72}$, slightly more sodic than the theoretical deduction of An_{40} (andesine) from the normative calculation.

Modal analysis is not entirely satisfactory because of the difficulty of differentiating between fine grains of pyroxene and olivine, and the variability of the material. The following would, however, seem to be a fair approximate assessment of the mode:—

Metal. Nickel-iron (kamacite) + sulphide (troilite) 10 - 15

Silicates. Ferromagnesian (olivine + hypersthene) 80±

Oligoclase 3 - 10

Microscopic study using reflected light allowed a clear distinction between kamacite and troilite. The later developed veinlets are entirely of sulphide. Bright reflectant specks aggregated with the kamacite may be schreibersite.

Texture and Microscopic Structure

The texture and structure are very variable. Chondrules provide the most striking structural feature: these mostly show well-rounded shapes (Plates 3 A, B) but some are broken, and some appear to have been partly absorbed in the recrystallised containing mass, again losing their regular shape. The grated chondrules show no evidence of ever having possessed any regular shape (Plate 3C). In the strongly recrystallised areas the chondrular structure is often not apparent. The range of internal textures is that normally associated with chondritic aerolites; the granular type called microporphyritic, the fan forms showing an exocentric focus (Plate 3 D), and grated chondrules are all abundant, but monosomatic (single crystal) chondrules have not so far been recognised. Felspar and metal are absent from most of the chondrules. There are sparse metallic chondrules, either composed entirely of metal or of sulphide and cryptic isotropic material (glass?) associated with felspar (Plates 2 B, 3 E, F); the latter include both microporphyritic and fan forms.

The relationship of the felspar and nickel-iron (native metal and sulphide) to the ferromagnesians and to the chondrular insets is one of the most interesting features of this meteorite. In recrystallised areas both nickel-iron and felspar are interstitial to the ferromagnesian grains (Plates 4 A, B); often this interstitial growth is arranged in narrow stringers and there are very well defined veinlets of the same material (Plate 3 B). These stringers tend to terminate in peripheral fringes around the chondrules (Plates 3 A, B), but rare examples, such as that shown in Plate 3 B, cut through them. The relationship suggests a late mobilisation and introduction of nickel-iron (+ sulphide) and felspar into a chondrite showing only very limited development of these minerals in the form of sparse chondrules. There seems to be some evidence of the same fringing relationship of sulphide and felspar to sulphide/felspar/glass chondrules as seen in the silicate chondrules, and these too seem to have been early structures which have been later invaded by material identical with that which composes them. The alternative interpretation—that the sulphide/felspar chondrules represent crystallisation in spheroids from these stringers seems unlikely. Lovering (Moore, 1962, p. 195) has suggested a sequence of genetic phases in meteorites, and this felspar-metal invasion which seems to accompany recrystallisation seems to fit in well with this concept.

The classificatory terms of the older Brezina system, veined and recrystallised (crystalline), seem entirely justified by the structural and textural evidence.

The texture and mineralogy of the recrystallised areas (Plates 4 A, B) of this meteorite would be difficult to differentiate from that of some ultrabasic igneous rocks were it not for the presence of nickel/iron with subordinate sulphide rather than entirely combined in ore minerals—oxides and sulphides characteristic of such rocks. This comparison could well have a petrogenetic significance, in respect of the derivation of crustal igneous rocks from the mantle.

Chemical Analysis

Two full chemical analyses have been carried out on specimens chosen at random from the collection at the West Australian Museum. The only selective factor was that specimens of fresh appearance were chosen.

Before sending the specimens for analysis a set of specific gravity determinations was made on five of the fragments. The results obtained were 3.45, 3.46, 3.53, 3.54, 3.58; *Average* 3.51.

Results of analysis by Dr. A. A. Moss, British Museum (Natural History) are as follows:—

Analysis by the Method of Prior (1913). Lab. No. 2943.

Percentage Composition

Fe	6.31	TiO_2	0.10	MnO	0.29	Na_2O	1.04
Ni	0.99	Al_2O_3	2.98	FeO	14.07	K_2O	0.14
Co	0.05	Cr_2O_3	0.54	MgO	24.88	H_2O+	0.04
FeS	6.43	P_2O_5	0.09	CaO	1.89	H_2O-	0.09
SiO_2	39.95						

Total 99.88%

Normative mineral composition

Olivine (close to $Mg_{1.5}Fe_{0.5}SiO_4$)	46.94
Bronzite*	25.19
Felspar†	12.69

* The conversion of a meteorite analysis by Prior (1913) to normative values involved the allocation of excess $CaSiO_3$ to bronzite, a mineral that does not contain any calcium silicate. This seems without any real basis and it would perhaps be better to express the $CaSiO_3$ excess simply as $CaSiO_3$. However, in conformity with the accepted practice, the figure for bronzite given here includes $CaSiO_3$ excess: it must be noted that this will make the bronzite value somewhat higher than the expected modal orthopyroxene content.

† The felspar normative values are Or .84, plagioclase remainder (c.$An_{40}Ab_{60}$).

Ilmenite	0.18
Chromite	0.81
Apatite	0.21
Troilite	6.43
Nickel Iron (Ni/Fe = 1/6.3)	7.35

Molecular ratio MgO/FeO in Silicate Fraction — 3.14

A second analysis by the Government Chemical Laboratories, Perth, shows no significant divergence.

X-Ray Diffraction Studies

The following minerals were recognised in the course of X-ray diffraction studies carried out at the Physics Department, University of Western Australia.

Metallic Fraction

Kamacite

The sulphide could not be conclusively identified.

Silicate Fraction

Olivine ("forsterite")

Enstatite (60% certain identification)

Rankinite (only very doubtful identification since no calcium silicate has ever been recognised in meteorites).

The recognition of orthopyroxene of the enstatite-hypersthene series was confirmed by further X-ray diffraction studies of pyroxene separated from the meteorite by Mineralogists of the British Museum (Natural History).

In the course of his investigation of olivines from stony meteorites Dr. B. Mason has carried out optical and X-ray diffraction studies of olivine from this meteorite, and confirms that it is Fo_{75} Fa_{25} (written communication).

Acknowledgments

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Appendix

List of institutions holding specimens of the Woolgorong Meteorite—

- West Australian Museum (12113a, b and C, and thin sections 12283-12286)*.
- University of Western Australia (48334).
- Geological Survey, Western Australia (1/4878).
- Government Chemical Laboratory, Perth (N DC 3205).
- Kalgoorlie School of Mines.
- British Museum (Natural History).
- American Museum of Natural History, New York.
- Smithsonian Institute, Washington.

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* The photomicrographs used as illustrations 3a-3f, and 4a-4b were prepared from these thin sections.